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Feeding Guilds and Bill Volume of an Assemblage of Birds Present in Four Vegetation Covers of the Terrapreta PNR Guaviare-Colombia

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Abstract

Objectives: The objective was to determine the composition and distribution of feeding guilds and bill volume of an assemblage of birds in four vegetation covers within the Terrapreta Private Natural Reserve. **Methods:** The vegetation covers were classified using Corine Land Cover method. Six sampling zones were defined, and three rounds were conducted between February and May 2023. Feeding guilds were identified according to diet, substrate, and foraging. Birds were captured with mist nets, bill measurements were taken, and volume was calculated. To evaluate guilds with vegetation cover, Marimekko, Chi-square and linear regression were performed, to establish the relation between bill volume and feeding guilds, a Boxplot plot and Wilcoxon rank-sum test were performed in the Rstudio program V. 4.3.1. **Findings:** 211 individuals in 6 order, 18 families, and 49 species, were captured and seven feeding guilds were identified: the most diverse (30.61%) and abundant (19.91%) group was Insectivore-Frugivore. In contrast, Granivore-Insectivore and Insectivore-Animalivore, had two species (4.08%) and 11 individuals (5.21%) each. The most abundant guild was found in a High Dense Terra Firme Forest (34.12%) with the highest specificity in bill volume (0.04 cm^3 to 0.92 cm^3) with total length values ranging between 7.7 cm and 20 cm. The relation between vegetation cover and the proportion of feeding guilds were significant (X^2= 70.095, df = 18, p-value <0.05); feeding guilds and bill volume had statistically significant differences Wilcoxon rank-sum test (with a p<0.05). The impact on vegetation cover because of habitat transformation, especially on food resources, can be reflected in the guild structure, which can be interpreted as less ecosystem complexity, with the presence or absence of determined feeding guilds. **Novelty:** Functional traits, bill volume, and feeding guilds provide a tool to evaluate strategies for restoration process and contribute to management and conservation plans within protected natural reserves.

Keywords: Bill Volume; Birds; Feeding Guilds; Functional Traits; Guaviare; Vegetation Cover

1 Introduction

Deforestation is a growing global problem, mainly in South America[1,2], where the degradation of ecosystems has generated concern due to the deterioration of biodiversity, its interactions, and heterogeneity[2,3]. In the department of Guaviare, deforestation has been especially pronounced. Factors such as extensive cattle ranching, illegal mining, agricultural frontier expansion, unplanned transportation infrastructure, indiscriminate logging, and illicit crops are the leading causes of forest degradation[4–6]. In 2020, the Department of Guaviare recorded 15,000 hectares affected, representing 16% of all deforestation in Colombia[4,6].

Birds are crucial in measuring ecosystem transformation because of their presence at different trophic levels, their mobility, their high diversity, and their sensitivity to habitat transformation or natural environmental changes, making them ideal for measuring environmental perturbations based on their response to transformations, habitat requirements, and feeding habits, associated with the functional traits of the species[7,8]. Feeding guilds contain many ecologically similar subgroups within an assemblage and diverse species with similar food demand that they use analogously. The bird's beak adaptation is essential for feeding. The volume directly influences its diet and the way it uses food resources; therefore, these organisms are ideal for comparing coverage or environment with different conditions[9–11].

This study aimed to determine the composition and distribution of feeding guilds and the bill volume of an assemblage of birds in four vegetation covers within the Terrapreta Private Natural Reserve (PNR), Guaviare-Colombia. Additionally, we propose a contribution as a mechanism of analysis in ecological restoration processes.

2 Methodology

2.1 Study area

The study was carried out in the Terrapreta PNR located in the department of Guaviare in Monserrate district (Figure 1). The reserve has 37 hectares of forest and 38 hectares delimited as open areas in the restoration process. It is strategically located and contributes to conserving the Department ecological connectivity, bordered to the north by the Serranía de la Lindosa and to the south by Caño Trueno, a tributary of Caño Grande[12]. It has a monomodal precipitation regime with rainfall between April and July and an average annual temperature of 26 - 27 °C on the warm thermal floor. It has a very heterogeneous floristic composition characterized by numerous species of palms and xerophilous and macrocephalous plants[13].

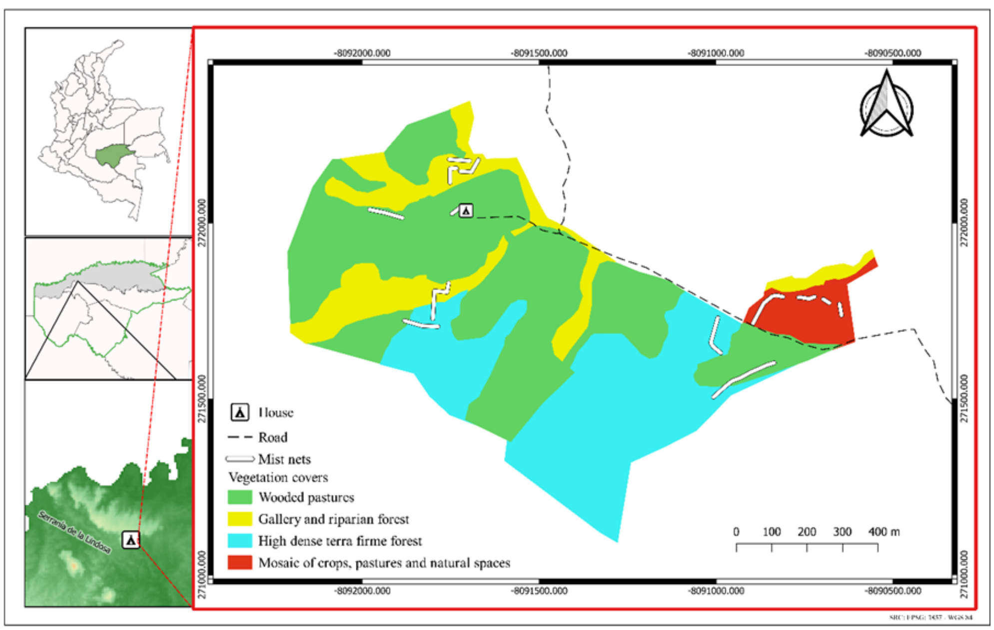

Fig 1. Map of the study area, highlighting four vegetation covers and the distribution of mist nets

2.2 Determination of vegetation cover

Four types of vegetation cover were established based on the Corine Land Cover method with different degrees of transformation and field verification: High Dense Terra Firme Forest (HDTFF), Gallery and Riparian Forest (GRF), Wooded Pasture (WP), and Mosaic of Crops, Pastures and Natural Spaces (MCPNS) [14]. Six sampling areas were determined: two zones in high dense forest, two in fragmented forest with pastures, one in gallery forest, and one in a mosaic of crops, pastures, and natural spaces. A round was defined as the sampling for each zone for 25 days. In total, three rounds were carried out between February and May 2023.

Transformed habitat is assumed to be places that have undergone processes of vegetation removal, with agriculture, cattle ranching, illicit crops, or presence of non-native species. Vegetation cover types include:

WP: land covered by pasture, trees taller than five meters distributed in a dispersed manner with tree cover more than 30% and less than 50% of the total area of the pasture unit, and the presence of non-native species.

MCPNS: areas of the territory occupied by crops and pastures in combination with natural spaces, occupying between 30% and 70% of the total area of the unit.

HDTFF: tree-type vegetation with an area equal to or greater than 70% of the total, canopy height between 5-15 meters, and no flood zones.

GRF: arboreal vegetation located on the margins of permanent or temporary watercourses.

2.3 Capture and measurement of functional traits in the bird assemblage

For the capture of birds, 96 meters of mist nets were used, with 30 mm of a net eye, during three continuous days per sampling zone, between the hours of 6:00 to 11:00 and 15:00 to 18:00. The nets were checked in every 30 minutes, and on the third day the nets were changed from one zone to another [8]. The captured individual was placed in cloth bags to be weighed with a spring scale.

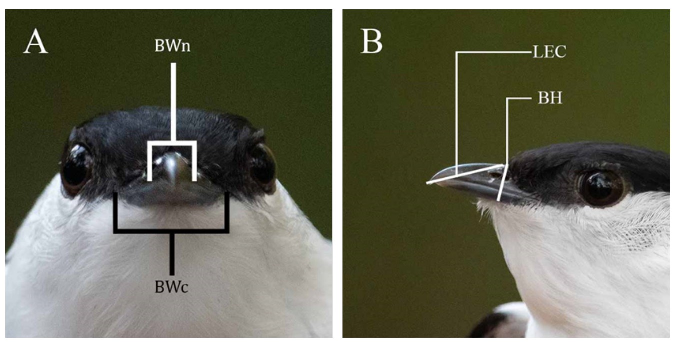

Fig 2. Morphometric measurements of the bills A) Bill width at nostrils (BWn) and bill width between commissures (BWc); B) Length of exposed culmen (LEC) and bill height (BH)

Morphometric measurements were recorded with the help of a digital vernier calibrator, and specific measurements of the bill were considered (Figure 2): bill height (BH), bill width between commissures (BWc), bill width at nostril level (BWn), length of the exposed culmen (LEC) [10]. With these measurements, the cone volume formula was applied to define the bill volume:

$$Bill\ volume = \frac{\pi \times (BWn/2)^2 \times LEC}{3}$$

Subsequently, the capture-mark-recapture method was used, the individual was marked using celluloid rings of different colors, recording the extremity on which the ring was placed, which allowed the organism to be recognized, the individual was released. This mark was not used in the Trochilidae family.

2.4 Feeding guilds

Bird species were classified according to three parameters: the main diet, the substrate used and the way of obtaining food, complemented with field observation and secondary information. [9]. Feeding guilds were determined as: Insectivore Frugivore (I-Fr) which feed mainly on fruits but supplement their diet with insects; Omnivore (O) which consumes a wide range of food including fruits, seeds, insects, small vertebrates and other available resources; Nectarivore (N) which extracts nectar from the flowers of plants; Foliage Insectivore (FI) which feed on insects located in the foliage of the entire vegetation column of the forest; Short-flying Insectivore (SFI) which feed on insects they catch in the air while flying short distances; Granivore-Insectivore (G-I) which feed mainly on seeds, supplementing their diet with some insects; and Insectivore-Animalivore (I-An) which obtain their food by visual perception from perches (species that feed on small vertebrates [amphibians, reptiles and small mammals] and some invertebrates [mainly insects] are counted within this guild)[15].

2.5 Data analysis

To determine the diversity of the feeding guilds in the vegetation covers, we used a Marimekko diagram and Chi-Square mean comparisonin Rstudio V. 4.3.1. To analyze the relation of the functional traits, the total length of the organism (TL) was used with the bill volume, as well as correlated with the vegetation covers and the feeding guilds, based on a linear regression analysis. To establish relation between bill volume and feeding guilds, a Boxplot plot and a Wilcoxon rank-sum test were performed in the program Rstudio V. 4.3.1.

3 Results

During the present study period a total of two hundred and eleven (211) individuals grouped in 6 orders, 18 families, and 49 species were captured (Table 1).

Table 1. Species composition and number of individuals captured

Family	Species	# individuals	Family	Species	# individuals
	Chionomesa fimbriata	4		*Ramphocelus carbo*	4
	Chrysuronia oenone	1		*Sporophila angolensis*	9
	Glaucis hirsutus	3		*Saltator maximus*	2
Trochilidae	*Phaethornis malaris*	3	**Thraupidae**	*Sporophila minuta*	1
	Phaethornis atrimetralis	3		*Thraupis episcopus*	3
	Phaethornis hispidus	20		*Stilpnia cayana*	2
	Thalurania furcata	13		*Tersina viridis*	1
	Heliomaster longirostris	1		*Sporophila bouvronides*	1
Columbidae	*Leptotila rufaxila*	1	**Tytiridae**	*Pachyramphus polychopterus*	1
Momotidae	*Momotus momota*	3		*Pachyramphus marginatus*	1
Cuculidae	*Crotophaga ani*	5	**Troglodytidae**	*Troglodytes aedon*	3
Fringillidae	*Euphonia chrysopasta*	1	**Turdidae**	*Turdus ignobilis*	6
Furnariidae	*Dendrocincla fuliginosa*	6		*Catharus fuscescens**	4
	Glyphorynchus spirurus	11		*Empidonax alnorum**	6
Icteridae	*Cacicus cela*	1		*Leptopogon amaurocephalus*	7
Mimidae	*Mimus gilvus*	1		*Mionectes oleagineus*	2
Parulidae	*Leiothlypis peregrina**	1		*Myiarchus tuberculifer*	5
	*Setophaga striata**	5	**Tyrannidae**	*Myiodynastes maculatus*	2
	Ceratopipra erythrocephala	5		*Myiozenetes cayanensis*	1
Pipridae	*Manacus manacus*	23		*Pitangus lictor*	1
	Machaeropterus striolatus	4		*Pitangus sulphuratus*	5
	Myrmotherula axilliaris	9		*Poecilotriccus sylvia*	8
Thamnophilidae	*Thamnophilus amazonicus*	3		*Tyrannus melancholicus*	3
	Cercomacroides tyrannina	2	**Vireonidae**	*Vireo olivaceus**	3
			Capitonidae	*Capito auratus*	1

***Migratory species**

The most representative species were *Manacus manacus* (10.90%) and *Phaethornis hispidus* (9.47%). Five boreal migratory species were found (10.20%): *Leiothlypis peregrina, Setophaga striata, Catharus fuscescens, Empidonax alnorum* and *Vireo olivaceus*, representing 9% of the total number of individuals captured (Table 1 *).

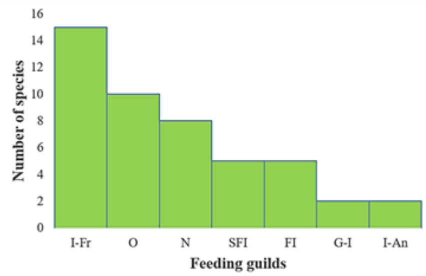

Fig 3. Number of species by feeding guilds

The recorded species were grouped into seven feeding guilds: the most diverse was Insectivore-Frugivore (I-Fr) with 15 species (30.61%), followed by Omnivore (O) with ten species (20.41%), and Nectarivore (N) with eight species (16. 33%). Foliage Insectivore (FI) and Short-flying Insectivore (SFI) were less represented with five species (10.20%) each, followed by Granivore-Insectivore (G-I) and Insectivore-Animalivore (I-An) with two species each (4.08%) (Figure 3). The feeding guilds with the highest abundance of individuals were I-Fr (n = 72, 32.12%) and N (n = 48, 22.75%). The least abundant guilds were FI (n = 18, 4.74%), G-I (n = 11, 5.21%) and I-An (n = 11, 5.21). The boxplot representation and the Wilcoxon rank-sum test showed significant differences between feeding guilds and bill volume.

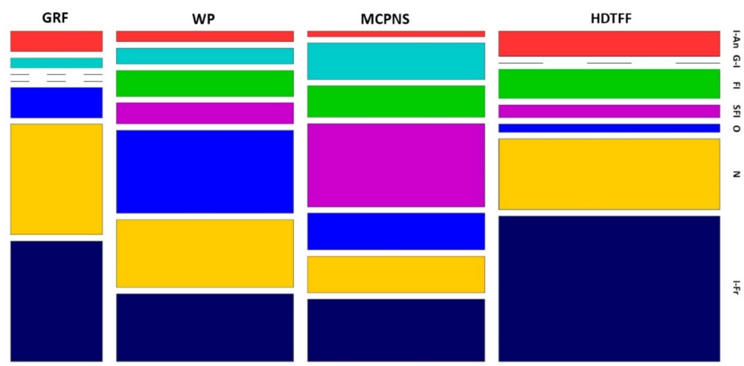

Fig 4. Marimekko plot between seven bird feeding guilds in four vegetation covers (X^2= 70.095, df = 18, p-value <0.05).

All feeding guilds were present in the MCPNS and WP coverages. SFI and FI guilds were not present in the GRF coverage, G-I guild was not reported in the HDTFF coverage. The relation between vegetation cover and the proportion of feeding guilds were significant (X^2= 70.095, df = 18, p-value <0.05). The vegetation cover that presented the greatest diversity of feeding guilds was HDTFF (Figure 4), where I-Fr represents 50% of its totality and corresponds to the guild with the highest abundance (34.12%), followed by the Nectarivore (22.74%) and Omnivore (13.27%) feeding guilds. The boxplot representation and the Wilcoxon rank-sum test showed significant differences between feeding guilds and bill volume (with a significant level of $p < 0.05$) (Figure 5).

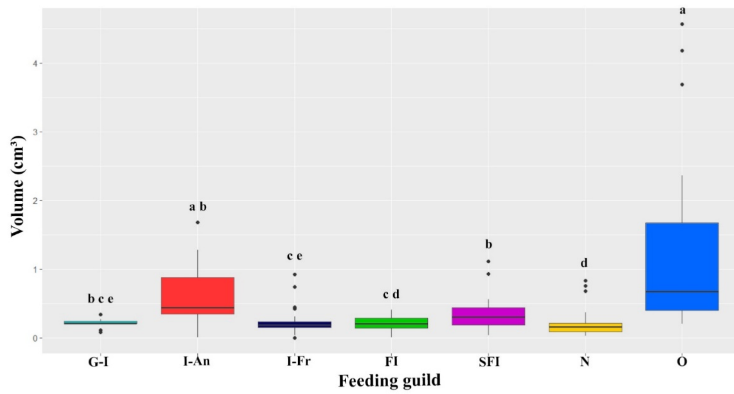

Fig 5. Box plot representation and Wilcoxon rank-sum test results of feeding guilds and bill volume. Different letters within feeding groups indicate statistically significant differences at a significant level of $p < 0.05$

The relation between the total length and bill volume (**Figure 6A**) is grouped mainly in the FI guild with values ranges 8.7-14.7 cm for total length and 0.01- 0.41cm^3 for volume, followed by I-Fr (total length = 7.7- 20 cm, volume 0.04- 0.92 cm^3). Guild N presented values for total length 8.75-21cm and bill volume 0.03-0.83cm^3. On the other hand, a broad size spectrum of individuals was observed in the feeding guild O, which comprises the most dispersed values of the sample: 14.4-43.8 cm for total length and 0.20-4.57cm^3 for bill volume. This relation between bill volume and total length for all the guilds is directly proportional (R^2=0.754) and highlights the influence of total length on bill morphology and suggests a specific adaptation of birds according to their body size and diet. (Figure 6)

Vegetation cover with the highest abundance was HDTFF (Figure 6**B**) with values in a specific range: 8.1cm-22.8cm for total length and 0.01-1.68cm^3 for volume, demonstrating that individuals present with both small size and small beaks. This is consistent with the overlap of data (Figure 6 **A, B**) between HDTFF and I-Fr, being the most representative guild of the sampling, followed by MCPNS coverage (8.5- 31cm for total length, 0.04-1.85cm^3 for volume).

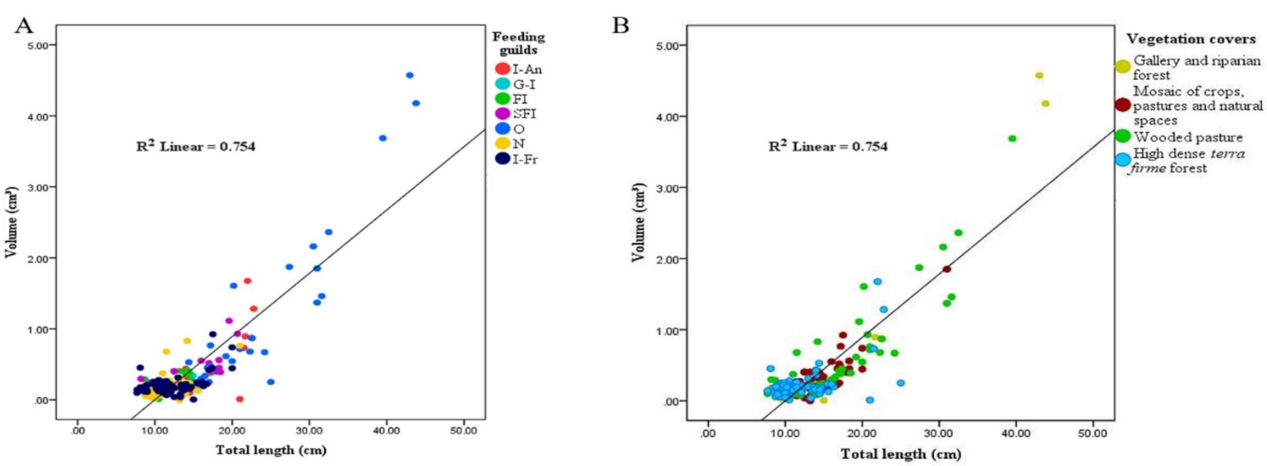

Fig 6. Linear regression between Total length (cm) and volume (cm^3) categorized in A) Feeding Guilds B) Vegetation Covers

GRF has the least abundant vegetation cover with 29 individuals; however, it presents a great diversity of feeding guilds and the broader size spectrum (8.1-43.8cm for total length, 0.004 - 4.57cm^3 for volume). These birds present with bills of considerable size compared to total length, but also contain individuals with smaller bills in proportion to their body size. WP presented morphometric values ranging from 7.7 cm to 39.5 cm in total length and from 0.08 cm^3 to 3.69 cm^3 in beak volume.

4 Discussion

The most abundant species in this study was *Manacus manacus*; its distribution in the understory of the HDTFF is evident mainly by its diet, which is based primarily on fruits and insects characteristic of this vegetation layer[16]. We found that the average total length of *Manacus manacus* was 11.02 cm, while the average volume of its beak was 0.21 cm^3. These morphometric values strengthen the adaptation of this species for the feeding guild I-Fr[16], where the marked ratio between the volume index of the mouth cavity and its body allows it to effectively exploit a great variety of fruits present in both preserved primary forests and secondary forests with a diversity of plant species[16,17]. *Phaethornis hispidus* was the second most abundant species and was found in 11.42% of HDTFF, 8.93% of MCPNS, 8.93% of WP, and a smaller proportion in GRF (6.89%); however, this species is commonly associated with flooded ecosystems typical of the Amazon (varzea forest, floodplain)[18].

Boreal migration occurs from September to May, overlapping with the sampling season, which supports the capture of migratory species in the vegetation cover. Search for food availability, climatic conditions, and reproductive opportunity allows the presence of migratory species contribute to the species composition, and temporarily establish a greater diversity of species in the habitat[19].

The Insectivore-Frugivore (I-Fr) feeding guild is described as sensitive in multiple investigations; it is composed of forage species, showing specificity in the exploitation of food resources[20–22]. The large percentage of this guild, specifically in HDTFF (Figure 4), can be related to the sampling and the availability of specific feeding niches for birds of conservation importance. The specific climatic conditions in this vegetation strip have a higher degree of humidity throughout the year and less exposure to the sun, favoring the presence of insects and the growth of fruit plants. These characteristics increase the possibility of encountering birds of the I-Fr guild[23,24].

The N and FI guilds presented the most specific bill volumes, differentiating them from the other groups (Figure 5). The Nectarivore guild, represented by hummingbird species, has a marked adaptation to the nectar resource. Their niches tend to overlap, showing a homogeneous distribution in the study coverage independently of the transformation presented by each habitat, and the resources are being used in the same way[25].

The slight variation in the ranges between total length and bill volume of the FI guild individuals (Figure 6**A**) accounts for the specificity of the diet. This morphometric adaptation in beak volume may be due to the decrease in competition for this resource in the different coverage and the subsequent reduction in energy expenditure that this entails[26]. The way of capturing food, the type of substrate, and the vegetation stratum have specific functions that may cause the morphology of each species to manifest in a specific way for a microhabitat, resulting in the absence of the guild in certain coverage, such as GRF[27].

On the contrary, the Omnivore and Insectivore-Animalivore guilds presented the most dispersed distribution of bill volume (Figure 5), probably due to the variety of their diet. The O guild is mainly found in WP where habitat transformation is more evident, favoring diverse foraging, whereas HDTFF cover may offer a wider range of prey sizes for I-An (Figure 6).[24,28]

SFI is the most abundant guild in MCPNS; the heterogeneity in the structure of the landscape can favor the availability of food in this cover, increasing the proliferation of insects by the variation of light and temperature. This contributes to the use of new niches that cannot be exploited by several species, where the border between the forest and the cultivation areas suggests zones of more significant benefit for these insectivorous species[28]. Likewise, the absence of this guild in the GRF coverage contrasts with prior studies where the percentage of this group was significant in their sampling. In this study data collection at the end of the dry season and the beginning of the rainy season, could have influenced the availability and distribution of resources used by these individuals[9,27].

In HDTFF, the absence of the G-I guild could suggest that the drought period at the beginning of the study could decrease this food resource where this habitat could not be exploited. Numerous studies mention the dominance of this guild in early forest successional stages, where there is a high degree of habitat transformation[26,29]. Furthermore, the diversity of feeding guilds in degraded areas (WP and MCPNS) can be attributed to the ability of generalist species to adapt to these degraded environments[25]; however, these coverage present a lower proportion of individuals and species diversity than habitats with a higher degree of conservation.

The bill volume values were clustered in the HDTFF cover which can be attributed to the existence of a greater variety of food resources, resulting in a high specialization in the use of the bills and their relation with great ecological complexity. This contrasts with the three remaining vegetation coverage BGR, WP and MCPNS; beak volumes were scattered, possibly associated to the lower supply of food resources and habitat degradation, which may represent difficulties in harnessing resources, therefore favoring species with generalist diets[30].

The change in the availability of food resources and its impact on vegetation cover because of habitat transformation can be reflected in the feeding structure, as shown in the current study. This can be interpreted as less complex for the absence of feeding guilds, and the dominance of each guild in the habitat sampled[31]. In addition, functional traits can give early signals of the response of birds to disturbances, which allows faster and more efficient detection of environmental impacts and the prioritization of plans for the conservation of strategic ecosystems and areas in the process of regeneration or ecological restoration [22,24].

Although the individual birds' adaptability to human disturbances is not as affected by the diversity of feeding guilds present in degraded areas such as WP and MCPNS, the impact of the decrease in the health of habitats and bird assemblages is reflected in the vegetation cover. The morphometry of the bill observed from the volume provides a perspective of analysis on the relation between feeding guilds and the birds' response to human disturbances in different vegetation covers of restoration processes. This is observed in the species richness and abundance of individuals [32–34].

Could the proportion of feeding guilds and bill volume be considered an indicator of the degree of habitat transformation? In this study, the proportion of feeding guilds with more specific diets occurred in less transformed cover, in contrast to the presence of the G-I guild only in transformed habitats. The high specificity of bill volume was observed in the I-Fr guild and found in greater proportion in the less transformed cover HDTFF. That means that this feeding guild could be sensitive to human disturbances; therefore, it is important in the evaluation of the state of habitats, and its presence in covers symbolizes higher ecosystem complexity. Besides, the WP and MCPN coverage show bill volume morphometric values dispersed, with generalist species that reflect processes of less ecological complexity. This information may be helpful when monitoring a restoration process in these ecosystems. How the bill volume values behave over time in a given ecosystem could reflect whether its restoration is being carried out successfully in the tropical rain forests of the northern Colombian Amazon.

5 Conclusions

The highest abundance of organisms and the highest number of species were found in HDTFF cover, while GRF had the lowest abundance and species diversity. The seven feeding guilds were present in the WP and MCPNS coverage. Nectarivore and Foliage Insectivore guilds exhibited specific bill volumes, while the Omnivore and Insectivore-Animalivore guilds displayed a more dispersed distribution of bill volumes. For the Insectivore-Frugivore guild (I-Fr), bill volume specificity was observed mainly in less transformed and abundant habitats such as HDTFF and more dispersed volumes in Omnivore guild (O) at WP and GRF. The most generalist species of bill volume and feeding guild were found in the most transformed covers; therefore, the relation between feeding guilds and bill volume can provide essential information on the morphometric adaptations of a bird assemblage in response to degree of habitat disturbance.

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